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P.I.: Ute C. Herzfeld
Title: Geostatistical Methods for Seafloor Classification and Scaling Laws
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Relationship to Long-Term Research Objectives: My general long-term research objective is the development and application of adequate high-level mathematical techniques for the analysis of spatial data, in particular for remote-sensing data such as acoustic, seismic, bathymetric, and other geophysical data. My interest is in interdisciplinary work in mathematics, measuring techniques, acoustics, environmental information, geology and geophysics. A major objective of the ARSRP is to develop an understanding of the interaction between physical properties, seafloor roughness, backscattering, and acoustic signals. The development of adequate mathematical techniques is an essential part of this. Mathematical techniques are being developed especially for the analysis of data collected during the ARSRP 1992 and 1993 cruises. The method and software, however, are written in a general way, so its application is not limited to the ARSRP data analysis, but may also provide a useful tool in the analysis of any spatial data set in deep and shallow water. Work performed in FY 1994 concerns development and application of an automated method for quantitative classification of the seafloor, (1) according to seafloor properties of different units throughout the ARSRP survey area, and (2) depending on scale.

(1) Geostatistical seafloor classification

Seafloor classification is aimed at quantitatively characterizing seafloor properties such as roughness and anisotropy and at using such spatial characteristics to automatically distinguish geological provinces. As part of the ARSRP data analysis, we have developed a geostatistical classification method (variogram classification method) that allows us to distinguish property classes of the seafloor. The idea of the classification method is to calculate directional variograms for a collection of test areas and to establish parameters characteristic of the seafloor morphology in the test area. (The variogram is the lag-dependent spatial structure function used in geostatistics, Journel and Huijbregts, 1989). The variograms are filtered, parameters extracted, and a feature vector is composed of the parameters. Discrimination algorithms are applied to extract and combine features and associate a seafloor class. In the past year (FY 94), we have concentrated our efforts on identification of parameters, implementation of more effective numerical algorithms for composition of feature vectors, implementation of better decision processes, and graphical improvements. The mathematical principles of the geostatistical classification method are derived in Herzfeld (1993a) and have been demonstrated to the ARSRP community at meetings (Herzfeld, Marra, Stewart 1993b, Herzfeld 1993c).

In Figure 1, several examples of the geostatistical classification applied to HYDROSWEEP bathymetric data from the Western Flank of the Mid-Atlantic Ridge at 25° 45'N to 26° 40' are given. We collected the bathymetric data during the ARSRP 1992 geology and geophysics cruise (Chief Scientists Brian Tucholke and Marty Kleinrock, WHOI). Parameters include direction and spacing of abyssal hill terrain, significance of abyssal hills determined by slope and normalized height of variogram features, isotropy/anistropy, and absolute variance. If the parameters and algorithms are well-chosen, then the output map has connected areas of the same color, representing an area where one seafloor type dominates. In examples 1 and 2 in Figure 1 (panels 3-4) this is very well documented. Special attention has been given to characterization and discrimination of pond areas and boundaries between pond areas and adjacent steeper terrain. In summary, the examples show that the discontinuity,

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marked by the sediment ponds, is easily visible in all examples. Parameters can be combined and properties overlain. We distinguish classification with direction searches and examples where a direction is predetermined by the user. (The examples are taken from Herzfeld and Higginson, 1994). The examples show that the goals of (1) characterizing sediment ponds by statistical parameters, (2) distinguishing abyssal hill terrain of variable spacing and of simple and complex nature, (3) segmentation of the area based on roughness criteria and (4) automated geologic and morphological mapping can be achieved with our method.

The geostatistical classification has also been carried out for the entire 600 km by 250 km area at 25°45'N to 26°40'N on the Western Flank of the Mid-Atlantic Ridge, where we collected HYDROSWEEP bathymetric data during the 1992 ARSRP geology and geophysics cruise. This is an attempt at automated geologic mapping. The resultant maps of roughness and geologic/morphiologic provinces are presented in Herzfeld (1994) and can be compared to results described in Tucholke and Lin (1994).

(2) Scaling Problems

In FY 94, I have worked on final stages of publications on the scaling problem. One contribution came out as part of a book entitled "Computers in geology- 25 years of progress", edited by John C. Davis (University of Kansas) and myself for the 25th Anniversary of the International Association for Mathematical Geology.

A few weeks ago we received a copy of the first high-resolution bathymetric data set from the 1993 ARSRP experiment (Kenneth Stewart and Brian Tucholke, WHOI). This will finally allows us to answer the question of scaling laws that determine the statistical properties of the seafloor in the ARSRP study area ("fractal question"). A first analysis of the high-resolution topographic data conffirmes that the seafloor is smoother at the 5m resolution than at the 100m resolution and has different spatial characteristics (as indicated in our earlier analyses of scaling properties, Herzfeld 1993b, Herzfeld et al. 1993a). The next steps will include a quantitative analysis leading to scale- dependent descriptors, specific of different seafloor types of the ARSRP area.

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